The development and implementation of charging infrastructure in the southeast part of Norway

ESST

The European Inter-University

Association on Society, Science and Technology

Birgitte Lunder Ween

University of Oslo

Faculty of Social Science

Centre for Technology, Innovation and Culture

Innovation and global challenges

October 2013

Word count: 16 438

2013

MA Thesis, Centre for Technology, Innovation and Culture

http://www.duo.uio.no

Acknowledgments

To carry out this study has been both fun and challenging. Several people deserve gratitude. First and foremost I would like to thank Allan Dahl Andersen. Thank you for good supervision! Without you, this thesis would not exist. Furthermore, I will thank my dear Bjørn-Arild Dahl. Thank you for always supporting me, being incredible patient and handling my ups and downs throughout the processes. You are amazing! I would like to thank all my informants for finding the time to be interviewed and sharing their valuable knowledge. I hope that some of my findings are of interest to you! A big thank you to Aina and Sofie for finding time in your busy secludes for proofreading my thesis. You know how much I appreciated it! Finally, I want to show gratitude to the rest of my family and friends for your understanding thought this intense period. You are the best.

Abstract

This thesis explores the development and the diffusion of the charging infrastructure in Oslo and its surroundings. Due to the rapidly increasing demand for electric vehicles, which in turn generates a great need for charging infrastructure, the aim of this study is to identify barriers in the development- and diffusion processes. Furthermore, the thesis analyses the business cluster Electric Mobility Norway and seeks to explain how it contributes to the development and diffusion of charging infrastructure. In this regard, several actors have been interviewed and observed. Empirical data have been analysed through the use of the framework technological innovation systems. In light of the conducted data, it has been identified great uncertainty and a lack in cooperation between the actors, which slow down the development- and diffusion processes. Furthermore, it has been argued that the businesses cluster Electric Mobility Norway contributes positively to these shortcomings. In the virtue of being a cluster, EMN has the opportunity to reduce the uncertainty and facilitate an arena where actors interact and cooperate.

Table of Contents

1.0 BACKGROUND AND CONTEXT

1.1 Climate challenge

Due to much emission of carbon dioxide among other types of greenhouse gases the world is facing a climate challenge. This leads to global warming. If the humankind does not change their way of life, this will have grave consequences. In order to reduce the emission of greenhouse gasses the role of innovation and technology are crucial. We need to "switch to more efficient, carbon-saving technologies or toward a non-fossil energy sources like renewable" (Unruh 2000: 818). The Norwegian authorities have, in accordance with the European Union Directive, committed to reduce their emissions of greenhouse gases with 30 percent by 2020. They also committed to be completely carbon neutral by the year of 2050. Compared with most other countries, Norway is in an especial position. More than 95 percent of the electricity supply is already renewable. To meet the goals, Norway therefore has to engage in other activities than decarbonising the electricity supply (FuelCellToday 2013:5-6).

Today, the transport sector is the biggest source of domestic emissions in Norway. Emissions from the sector have increased drastically, with more than 30 percent since 1990. Consequently, Norway is currently over the European average per capita regarding emission from transportation. 14 percent of the total emission of greenhouse-gases in Norway is from road traffic (FuelCellToday 2013: 5-6). Thus, in order to meet the goals to reduce the emissions of greenhouse gases it is essential to do changes within the transport sector. To implement new environmental friendly technologies and gradually replace them with the today's fossil fuel technologies will reduce the emission of greenhouse gasses in Norway considerably.

1.2 Electric vehicles

One of several types of environmental friendly technologies within the transport sector is the electric car (EV). The electric vehicle is not a new technology, as it has existed since the eighteen thirties (Cowan & Hultén 1996: 65). However, the electric vehicle has not been competitive. The gasoline car won the market. Today trends have changed, and electric vehicles have become a part of the fleet of automobiles in Norway. In June 2013, 12 993 electrical vehicles were driving on Norwegian roads. Statistics shows that this number is increasing rapidly. After the first two quarters of 2013, the number of electrical vehicles had increased by approximately 30 percent since the end of the year 2012 (Grønn bil). In Norway, electric cars represent approximately 2,9 percent of the total market share of passenger cars (Kvisle[1], 2013). This might sound insignificant, but in comparison with other countries this number is high. In fact, Norway is the country with the most electric cars per capita (Nørbech, 2011). Based on this, there is an increased demand for charging infrastructure.

1.3 Infrastructure

There is a consensus among scholars that physical infrastructure plays an important role in order to make technologies develop and diffuse (Andersen & Wicken 2013: 5). To change to more environmental friendly technologies there is a great need for developing new infrastructure. There is no doubt that electric vehicles require charging stations in order to function. A successful transition to environmental friendly technologies requires changes within the supply- and the demand side, in addition to the development of a supporting infrastructure that facilitates the supply and demand (Andersen & Wicken 2013: 4). The supply side involves a large-scale diffusion of the new technology, its possibility to overcome the existing technology, and to satisfy the demand. Furthermore, a change at the demand side involves users changing their preferences so it fits the new technology (Andersen & Wicken 2013: 4). In innovation studies there has been a broad focus especially on the supply side. However, despite of the acknowledgment that infrastructure is of fundamental importance in order to make technologies evolve, infrastructure has received limited focus in the literature (Andersen & Wicken 2013: 12). This thesis, by focusing on development and diffusion of charging infrastructure, is contributing to highlight the role that infrastructure is playing in order to change to more environmental friendly energy sources.

Later on there will be argued that it is fruitful to understand infrastructure as a system consisting of many components. In order to build a new system of infrastructure a systemically change is needed. In this regard the business cluster Electric Mobility Norway is of interest.

1.4 Electric Mobility Norway

Electric Mobility Norway (EMN) is the name of a relatively new business cluster that stretch from Kongsberg to Oslo in the southeast part of Norway. The cluster consists of 15 actors from different industries. The project can be considered to be in an initial phase. Their vision is to be an “industrial cluster that creates and takes attractive international positions for future-oriented transport solutions for electric-based cars” (EMN.no). They believe that if electric vehicle will have a real breakthrough, new technologies both inside and outside the electric vehicle are required. Through facilitating the actors to share and diffuse knowledge, the members of the cluster will be in a better position to develop solutions making the electric vehicle more attractive, including solutions linked to charging infrastructure. EMN is financial supported by multiple public bodies in addition to the county municipality of Buskerud.

1.5 Research questions

Although Norway is world leading in the use of electric vehicles, the market share for the EVs is still low. There is a need for identifying the barriers in the process regarding development and implementation of charging infrastructure. When one becomes aware of the barriers, one can optimize the implementation process. Currently, the distribution of chargers in the different municipalities of Norway is uneven. While the municipality of Oslo had 712 inhabitants per charging point in 2012, the municipality of Asker had 1 056 inhabitants per charging point, although the EV-density in Asker is the highest in Norway (Kvisle[2], 2013). These two adjacent municipalities represent the large variations of EV density in Norway. As previous mentioned, the number of EV-drivers is rapidly increasing, which again create an increasing demand for infrastructure. So far, the implementation of infrastructure is not correlated with the sale of electric vehicles (Norsk elbilforening 2013). Hence, due to the challenges listed above, it is critical to identify barriers in the process of development and diffusion of charging stations in Oslo and its surroundings.

The following research questions are to be answered in this research paper:

What are the barriers regarding the implementation of charging infrastructure in Oslo and its surroundings?

"*How is Electric Mobility Norway contributing in this regard?"*

Through answering these research questions, the thesis will hopefully contribute with a broader comprehension of implementation of charging infrastructure. Furthermore, the aim of the study is to highlight the role of infrastructure within a perspective of transitions. Electric Mobility Norway will in the thesis get explicit attention as it is an accredited cluster that attracts several significant actors within the industry. Furthermore, EMN receive much economical support from official authorities. It is therefore of interest to analyse if the cluster contributes to diffuse electric mobility; if the outcome of the financial support benefits the society.

1.6 Structure and literature

In order to answer the research questions, there is a need for a broader understanding and discussion of infrastructure within the context of regime transitions. The thesis is structured as follows. In chapter 2, technological change will be discussed. The chapter illustrates the complexity of a transition from today's situation, towards a low-carbon society. The two main theoretical frameworks focusing on technological change, the multi-level perspective and technological innovation systems, will be introduced briefly. Furthermore, in order to answer the research questions there is a need for conceptualizing the term "infrastructure", which will be done in chapter 3. Here the focus will be on infrastructure through a dynamic perspective. Chapter 4 will present the methodology and in this regard discuss some ethical aspects. Chapter 5 is dealing with the analysis, and the empirical findings will be presented and reflected upon. In the light of the empirical findings the research questions will be answered and discussed. Finally the conclusion is drawn in chapter 6.

2.0 TECHNOLOGICAL CHANGE- A LOW CARBON TRANSITION

As already elucidated, in order to reduce the climate crises that the world currently faces, a change towards more sustainable technologies is needed. A shift from gasoline pumps to charging infrastructure is one example. However, to change from one technology to another is a complex process in several ways. The frameworks of multi-level perspective and technological innovation systems are major frameworks for analyzing technological- and innovations aspects of low-carbon transition (Markard & Truffer 2008). These frameworks will be presented later in the chapter. Furthermore, it has been suggested that the two frameworks complement each other and are therefore of relevance to use together (Markard & Truffer 2008) Hence, the thesis will follow this idea.

2.1 Multi-level perspective

Multi-level perspective is a framework which emphasis that technological change occurs through interaction between three levels; socio-technical regimes, socio-technical landscapes and niches. One of the key points of the framework is to illustrate transformations from one regime to another (Markard & Trufffer 2008: 597).

2.1.1 Socio-technical regime

A socio-technical regime is “a coherent, highly interrelated and stable structure at the meso-level characterized by established products and technologies, stocks of knowledge, user practices, expectations, norms regulations, etc.” (Markard & Truffer 2008: 603). As the definition indicates, one can understand a socio-technical regime as a dominant production structure (Markard & Truffer 2008: 613). Although a socio-technical regime is stable, changes do occur. However they are not significant enough to fundamentally change it (Geels 2007: 128). Hence, one can argue that a socio-technical regime is inertia and dynamically stable (Markard & Truffer 2008: 605). Scholars stress the fact that we currently are living in a hydrocarbon regime, as the western world today mainly use gasoline from oil for transportation fuel, coal to generating electricity and natural gas for space heating (Rip & Kemp 1998: 381).

Unruh argues that the world today is locked into the hydrocarbon regime (Unruh 2000: 817). “Lock-in” is a term reflecting stability. The notion is based on that today’s choices are depended on yesterday’s choices. Locked-in technologies are often preferred although new and better solutions have entered on the market (Corvellec, Campos & Zapata 2012: 2). Locked-in technologies are therefore a main barrier for the establishment of new technologies in the society (Vooren, et al. 2012: 98). The QWERTY-keyboard is a frequently cited example. The gasoline car is another one.

As previously mentioned the electric vehicle is not a new technology. The first electrical cars were on the roads in the eighteen thirties. In the eighteen nineties the technology was rapidly improving. Furthermore, the electric vehicle competed against the gasoline- and steam cars for market shares (Cowan & Hultén 1996: 65). Compared with gasoline cars, which were seen as noisy, dangerous and noxious, the electric vehicle had a good reputation (Unruh 2000: 821). At the turn of the century, electric vehicles were more popular than the other types of cars. However, this did not last for long. Due to events linked to the gasoline car; decreased oil prices, the organisational innovation of mass production of mass production of Ford and the increased comfort for passengers, the gasoline car won the market (Levende historie.no). Since then, the gasoline car has been the dominant technology on the roads.

The literature of innovation studies are emphasising the different reasons for why it is hard to overcome a locked-in technology. Technological-, social/cultural- and structural factors are often highlighted. Since unlocking a technological regime is not the main focus in this study, overcoming lock-in will not be further elaborated on (for elaboration see i.e. Rip & Kemp 1998).

2.1.2 Socio-technical landscape

A socio-technical landscape is defined as a “set of heterogeneous factors, such as oil prices, economic growth, wars, emigration, broad political coalitions, cultural and normative values, environmental problems” (Markard & Truffer 2008: 606). Changes in the socio-technical landscape may lead to pressure on an existing regime. Furthermore, the pressure can lead to changes in demand-pull and technology-push. Demand-pull happens when users change preferences, while technology push occurs when the government support a new technology through specific regulations and incentives. These processes may lead to the arise of new technologies (Vooren et al. 2012: 100). Thus, changes of socio-technical landscape may therefore lead to opening up a ”window of opportunities” where radical innovations takes place.

2.1.3 Niche

Niches is a term that is defined as “protected spaces or incubation rooms, in which new technologies or socio-technical practices emerge and develop isolated from the selection pressures of “normal” markets or regimes” (Markard & Truffer 2008: 605). Due to the isolation from the normal selection pressures niches increase the likelihood for the survival of new technologies (Rip & Kemp 1998: 335). Scholars argue that in order to unlock the current hydrocarbon regime, creation of niches where the selection pressure is controlled is the way to go (Rip & Kemp 1998: 382).

2.1.4 The three levels are interacting

In line with the definition, the climate crises the world is facing can be considered as a change in the landscape. This put a pressure on the hydrocarbon regime (Geels 2002: 1265). Electric mobility can be considered as an up-growing niche, which further put pressure on the hydrocarbon regime. Thus, the regime is currently in a situation where it is being pressured both from above and bellow. However, as illustrated, the hydrocarbon regime is stable. In order to change to a low-carbon society, a considerable pressure on the hydrocarbon regime is required. In this regard, competitive environmental friendly technologies need to be developed and diffused.

2.1.5 Multi-level perspective – weaknesses

The multi-level perspective is a suitable approach to utilize when analyzing the transformation from one regime to another. The approach is less powerful when discussing growth in development and diffusion of a particular technology. Instead of emphasising the growth process, MLP is mostly confined to the niche-level and says little about the actual transformation process from niche to regime (Markard & Truffer 2008: 609). One can think of electric mobility and charging infrastructure as a niche, trying to expand and becoming a socio-technical regime. In order to answer the research questions, this transformation process is essential for this thesis. Markad & Truffer suggest that this transformation process is better described and analyzed within the framework technological innovation systems. This approach is dealing with the emergence and growth of a particular technology (Markard & Truffer 2008). MLP will, in this regard contribute to highlight the context and environment in which the processes of development and diffusion of the technology operates (Markard & Truffer 2008: 613).

2.2 Technological Innovation Systems

The framework of technological innovation systems is a part of the literature of innovation systems. One of the main points in the literature is that innovation is an outcome of interrelations between different actors.

> Firms do not normally innovate in isolation, but in collaboration and interdependence with other organizations. These organizations may be other firms (suppliers, costumers, competitors, etc. or non-firm entities such as universities, schools and government ministries *(Edquist 2005: 182).*

The boundaries of an innovation system can be defined in various ways. It can be delimited geographically (national and regional innovation systems) by sector (sectoral innovation system), by technology, or as a knowledge field linked to a particular technology (technological innovation system) (Edquist 2005: 199) (Carlsson et al. 2002: 237).

“A technological innovation system is a set of networks of actors and institutions that jointly interact in a specific technological field and contribute to the generation, diffusion and utilization of variants of a new technology/ of a new product” (Markard & Truffer 2008: 611). When using the approach, the first step is to decide how to delimit the system. Although a TIS is focusing on a particular technology, it is essential to delimit the system geographically (Carlsson et al. 2002: 233). Furthermore, one may look at the technology as a particular product/ artefact or as knowledge field (Carlsson et al. 2002: 237). When the system is defined, one has to identify its three types of structural components.

As the definition above indicates, a technological innovation system consists of three types of components, these being; actors, networks and institutions (Bergek. et al. 2008: 410).

Some of the actors in a TIS can be identified by looking at the value chain. Actors such as special interests organizations, R&D institutions and public bodies may be of great importance (Bergek et al. 2008: 413). The actors within a TIS have all influence through their different contribution of resources to the system (Jackobsson 2011: 46). A TIS may consist of different types of networks, which can be both formal and informal (Bergek et al. 2008: 413). Within a network, transfers of tacit and explicit knowledge often occurs (Jacobsson & Bergek 2004: 5). When engaging in a network the resource base may often increase. This is considered to be an advantage. Institutions are the third element in a TIS. It refers to factors such as laws, regulations, culture and values (Bergek et al. 2008: 413). In other words, institutions regulate the interaction between the actors, and set the condition for innovative activities.

Actors, networks and institutions generate the dynamics in a TIS. These dynamics can be analysed through seven key processes - also called functions (Bergek et al. 2008: 413).

2.2.1 The seven functions within a TIS

Scholars within the field of technological innovation systems have identified different functions that are considered as important for a TIS in order to evolve and succeed (Bergek et al. 2008: 409). These functions can be understood as key processes, which have impact on the performance of the TIS. Through analyzing these key processes, the focus is on what being achieved in the system (Jacobsson 2011: 50). Exactly what type of functions that are emphasized varies to some extent in different literature. The set of functions that will be presented below is from the well-cited article “Analyzing the functional dynamics of technological innovation systems: A scheme of analysis” by Bergek et al. It is of importance to understand the functions as an analytical tool and not something that necessarily clearly exists in “the real world” (Jacobsson 2011: 55).

Knowledge development and diffusion

Development and diffusion of knowledge is crucial within a TIS. There is a consensus that knowledge as the basis of innovation activities (Edquist 2005: 184-185). When analyzing a system, it is essential to grasp the knowledgebase and its evolution, how the knowledge is created and how it is diffused (Bergek et al. 2008: 414).

Entrepreneurial experimentation

Technological innovation systems develop under uncertainty. In order to reduce risk, it is of importance that the actors in the system engage in entrepreneurial experimentation. When doing experimentation, a social learning process will occur, which will be of great importance (Bergek et al. 2008: 415-416). Innovations are not primarily an outcome of discovery, but an outcome of learning (Smith 2002: 15).

Influence and direction of search

In order for a technological innovation system to evolve, new actors have to enter the system, while existing actors have to remain. This requires that entering firms see opportunities and possibilities, in addition to incentives in order to make the firms willing to invest (Jacobsson 2011: 51). Examples may be, a demand from potential costumers, technical bottlenecks, crisis in today’s business, financial incentives or beliefs in growth potential due to changes in the landscape (Bergek et al. 2008: 415).

Market formation

A successful technological innovation system normally develops through three phases; nursing-, bridging - and mass market. (Bergek et al. 2008: 416). In the establishment phase, a TIS will often lack a market, as there is no demand (Jacobsson 2011: 51). Often, markets need to be stimulated or created (Jacobsson & Bergek 2004: 6). In this regard public policy is important. Factors such as financial incentives or public procurement are examples on drivers for market formation.

Legitimation

Legitimation is about social acceptance. “The new technology and its proponents need to be considered appropriate and desirable by relevant actors in order for resources to be mobilized, demand to form and for actors in the new TIS to acquire political strength” (Bergek et al. 2008: 416-417). This statement illustrates the importance of legitimacy in order to strengthen the other key processes within a TIS. Furthermore, legitimacy is not something that is given, but is gained through deliberate measures (Jacobsson 2011:52).

Resource mobilization

In order to evolve, a technological innovation system needs to mobilise different types of resources. Both human and financial capital is crucial. These types of capitals are seen as “basic input to all the activities within the innovation system” (Hekkert & Negro 2008: 586).

Development of positive externalities

The last key process mentioned by Bergek et al. is “development of positive externalities”. While the system evolves the different functions need to be strengthened. New actors entering the system are crucial in this regard, as new entrants often leads to a reduction in uncertainty and an increase in legitimacy. (Bergek et al. 2008: 418). Less uncertainty and more legitimacy will lead to positive externalities in the system (Jacobsson 2011:53). The fact that positive externalities often arise when new firms enter the system, illustrates that key processes not are developed in a vacuum, but is instead co-evolving. Hence, changes in one function often lead to changes in the others functions (Jacobsen & Bergek 2004:6).

2.2.2 Blocking- and inducement mechanisms

The functions may be weak or strong for different reasons. Scholars are in this regard pointing at blocking- and inducements mechanisms (Bergek et al. 2008: 421). Blocking mechanisms are factors that are obstructing the development of functions in a TIS. Examples are poor articulation of demand (Bergek et al. 2008: 422) and weak connectivity between actors within the system (Jacobsson & Bergek 2004:12).

Inducement mechanisms, on the other hand, strengthen the key processes in the system. Government policy supporting the TIS is an example (Bergek et al. 2011: 422). The two types of mechanisms are not only found internally within the system, but may be found externally, in its surroundings (Bergek et al. 2008: 420-421).

As previously mentioned, the aforementioned functions interact with each other. Entrepreneurial experimentation will for instance often lead to creation of knowledge, while increased legitimation may result in more demand and mobilization of resources. Since the functions within a TIS interacts, "vicious cycles" may occur. When a factor is blocking one of the functions it may lead to weaknesses in the other functions (Hekkert & Negro 2008: 587). A vicious cycle results in slowing down the growth of the technological innovation system (Hekkert & Negro 2008: 585). Due to the potentially big consequences, it is important for the actors in the system to be aware of and identify the blocking - and inducement mechanisms that influence the system negatively.

2.3 The role of infrastructure

Development and diffusion of infrastructure is essential in order to implement environmental friendly technologies. According to Freeman, new technologies, notably radical technologies, requires a particular infrastructure in order to emerge and diffuse (Freeman 2001: 121-122). Smith agrees. He stresses that physical infrastructure is crucial for the production and the implementation of a technology in a society (Smith 2009: 4). Even though scholars acknowledge the fundamental role of infrastructure, there is a limited focus on the term in the literature of innovation studies (Andersen & Wicken 2013:3). Andersen and Wicken suggest that infrastructure should be analysed explicitly in the context of transmission grids. They further argue that there are valuable reasons to analyse infrastructure as a technological innovation system (Andersen & Wicken 20013: 18-21). This thesis will follow Andersen's and Wicken's argumentation in the context of electric mobility charging infrastructure. Analysing the dynamics of infrastructure by using the framework of technological innovation systems, has to my knowledge, not been done before. In this sense, this thesis is a conceptual exploratory study. However, prior to the empirical analysis, there is a need for discussion regarding the term infrastructure.

3.0 INFRASTRUCTURE

3.1 Definition and discussion of the term

The term “infrastructure” is being broadly used, both in everyday life and in academia. However, there is no agreed definition of the term, and it is often used in a non-academic way (Smith 1997:90). The most common understanding of the term infrastructure is that it is “non natural resources that is collectively used by industry in the production and distribution of products” (Smith 1997: 90). Smith understands infrastructure in another way. In addition to recognize the term as physical artefacts, such as roads and electricity grids, he stresses that infrastructure can be seen as “knowledge infrastructure”, such as universities and libraries. Infrastructure will in this study be discussed in the light of a physical artefact.

Andersen and Wicken argue that infrastructure can be understood as a network that is of significance importance to the superstructure. (Andersen & Wicken 2013:9). As this definition illustrates, the term infrastructure make sense in relation to the term superstructure. While infrastructure refers to “understructure” as for instance roads and bridges, superstructure refers to cars and busses. As the aforementioned definition indicates, superstructure often depends on an infrastructure in order to function. Furthermore, in line with the definition above, to just consider roads as the needed infrastructure of electrical vehicles is limiting, as multiple components are of fundamental importance. If only the car and the road existed, the electric vehicles would still not function. Without other physical artefacts such as charging stations and an efficient electricity system, to drive an electrical vehicle would be impossible.

3.1.1 Infrastructure - unite the supply side and the demand side

As already mentioned in section 1.3, a successful transition from one technology to another requires changes within both the supply- and demand side. A change at the supply side involves a large-scale diffusion of the new technology, its possibility to overcome the existing technology and at the same time satisfy demand. A change at the demand side involves users changing their preferences to fit with the new technology (Andersen & Wicken 2013: 4). Factors that may influence user preferences may be governance policy, regulations or changes in values. Hence, a successful transition from gasoline cars to electrical vehicles requires changes at the supply side, such as a large-scale diffusion of the electric car. On the demand side it will be necessary that people change their preferences. There is for instance required a shift from values such as freedom and masculinity towards “green values”.

Changes at the demand- and supply side involve a destruction of the establishment of the dominant technology. “Creative destruction” is an illustrating term in this regard. When a new technology is created, the old one is often destructed (Tidd & Besant 2009: 15). In the chapter above it has been argued that deconstructing an old technology often is a complex process. Hence, changes at the supply-and demand-side are often considered to be difficult.

Changes from one technology to another does not only require changes at the demand- and the supply- side; in order to implement new technologies, supporting infrastructure is of vital importance (Andersen & Wicken 2013: 4). The ethanol sector in Brazil is an example. The county has done huge successes in building up an ethanol sector, which again has led to exportation of biofuel for transportation. The infrastructure is widespread, and alcohol pumps have been implemented at almost all gas stations. As a consequence, the sales of cars using biofuel have increased dramatically in the country. This is not the case in the United States, where there is a lack of investments in infrastructure and hence, the technology is not widespread (Andersen 2008).

For a successful transition to take place, the infrastructure needs to ”be transformed to facilitate supply and demand side changes” (Andersen & Wicken 2013:4). The infrastructure must facilitate the technology (to make it function). As for instance, electrical vehicles need to be charged in order to work. Furthermore, the infrastructure needs to be developed in accordance with user preferences. The way the infrastructure is designed, where it is located, how widespread it is, has to facilitate the demand. Power pylons are needed for the electricity system to function. However, power pylons are being buried in the ground for public interests. Roads are needed in order to make cars functions, but they are constructed where people live and not in waste areas. The number of charging stations installed highly depends on how many people that are interested in driving electrical vehicles.

Without having empirical evidence, it may seem that the supply and demand side sometimes develop faster than the infrastructure itself. If this is the case, it will lead to a situation where the infrastructure is not able to facilitate both the demand and supply side, which in turn will slow down the technology transition.

Furthermore, without having a suitable infrastructure, a successful shift from one technology to another is hard. Insufficient infrastructures will affect both the supply- and the demand side. For example, without any chargers, roads or electricity, the technology of electric vehicles will not function, and the result is no demand. By providing fewer charging stations than required, a situation where electrical vehicles will not reach their potential will arise. This will again lead to a decrease in demand.

3.2 Characteristics of infrastructure

Infrastructure has certain technical and economical characteristics. Firstly, infrastructure is multi-user. This means that many users utilize the same infrastructure, and duplication is therefore often pointless. For instance, people use the same roads and electricity and hence, duplication is unnecessary. Secondly, infrastructure is generic, in the sense that infrastructure is required for many, if not all types of economical activities. Thirdly, infrastructure is indivisible. One has to understand it as many parts related to each other and that they are inseparable (Smith 1997: 92). Smith argues that since infrastructure is characterized as indivisible and has multiple users, infrastructure is often large-scale (Smith[b] 2002:11). These characteristics illustrate how complex it is for private actors alone to build up a new infrastructure. Firms do have restricted resources and to cope with uncertainty and to carry out large-investment projects is therefore hard. Consequently, infrastructures have usually been provided by official authorities (Andersen & Wicken 2013: 9).

Although multiple types of infrastructures can be identified with the previous mentioned characteristics, there are exceptions. Infrastructures are for instance not always indivisible. The infrastructure facilitating electric mobility consists of components that are separable. This will be elaborated on later in the chapter.

3.3 The dynamics of infrastructure

To understand infrastructure in the way proposed above; as physical artefacts that are of fundamental importance for superstructure, uniting supply- and demand sides together, is a simplistic and constraining comprehension. Scholars within innovation studies argue that infrastructure should be understood in a broader way; as a socio-technical system (Kaijser 2004).

Thomas P. Huges introduced the term “large technical systems” (LTS) in 1983. He argues that it is not enough to understand a technology as one single artefact, but that one has to understand it in a broader view; as a system (Hughe 1983). Betz argues: “the concept of a system means to look at a thing, an object with a view to seeing it as a dynamic totality- displaying change, and encompassed in an environment” (Betz 2011: 224). Furthermore, a technological system consists of both physical- and non-physical parts. While physical components refer to the technology itself, non-physical components refer to regulations, norms, and multiple actors like investors, firms and others investing in and developing the technical components. Since nonphysical components in a LTS develops and shapes the physical artefacts, it makes sense to say that technical systems is socially constructed (Markard & Truffer 2006: 610). Although this is a common understanding of technologies, to understand infrastructure in the same way is not usual. However, scholars argue that in order to understand the dynamics of infrastructure one has to see it as a system. In order to analyse how infrastructure emerge and develop, it is too narrow to look at infrastructure as just physical elements. One also has to take into consideration the “soft” sides of the infrastructure, such as the developers and operators (Kaijser 2004: 154), as well as the regulations and norms that influence the development and diffusion. One way to do this is by studying infrastructure through a technological innovation system approach. This will be done in the following chapter.

Both the physical and the non-physical components within a socio-technical system are interrelated and coordinated. If you change one component, the others will somehow be affected. Changes or breakdowns in one component may have big consequences for the overall system. The term “seamless web” was introduced by Hughes and is a metaphor that illustrates the interplay and dependency between the components within such a system (Rip & Kemp 1998: 337). How interrelated the components are depends on the system, which can be either tightly or loosely coupled (Kaisjer 2005: 155). The tighter the components within the system interrelate, the more rigid is the system. If the components are tightly coupled, it will be difficult to change just one element within the system. Then you will need to change more of the components in the system, which are often a complex and a costly process. Consequently, changes in systems tend to be mainly incremental, following the same path as earlier innovations within the system. Instead of big radical changes, the system is being improved through incremental innovations (Markard & Truffer 2006: 610). Infrastructure is not only interrelated with the components within its system, but is also often interrelated with its superstructure (Andersen & Wicken 2013:3). Thus, one can say that changes in infrastructure often are path dependent. Path dependency is a well-known term in innovation literature, illustrating that decisions and choices are dependent on previously decisions. The same path is followed, which has lead to success in the past. Consequently radical changes within the system will seldom occur (Markard & Truffer 2006: 610). However this does not indicate that a system of infrastructure is totally static, but rather is dynamically stable (Andersen & Wicken 2013: 8).

3.4 New infrastructures are needed

As mentioned above, new technologies often requires a supporting infrastructure in order to diffuse (Andersen & Wicken. 2013:5). In some cases it is not enough with incremental innovations within the current system of infrastructure. Sustainable technologies will often require great changes in existing- or totally new systems of infrastructure. Different types of innovations require different degrees of new infrastructure, which can be linked to the work of Shumpeter and his classification of innovations.

Based on the work of Shumpeter, one may classify innovations based on how radical they are compared to the current technology. Shumpeter focused mainly on two types;

incremental- and radical innovations (Fagerberg 2005: 7). In addition, there are also disruptive innovations. These three types of innovations differ in their characteristics (Smith 2009:17).

As mentioned above, incremental innovation is the type of innovation that is the most common in regard to infrastructure. It does not change the characteristics of the existing technology, but rather improves it (Smith 2009:17). The different models of iPhone are examples. The latest model, iPhone 5, is very similar the iPhone 4S. Their characteristics are the same, but the new model has been improved and got new functions. The iPhone 5 case, illustrates an incremental innovation that do not demand a new system of infrastructure. Hence, the implementation of the incremental technology may not be a to big and complex act.

Radical innovation is the second type of innovation. “Here we are not thinking of a shift with respect to a single technical function, but rather a more encompassing change that alters the generic technologies that underpin many forms of technological and economic activity” (Smith 2009:19). While incremental innovations often occur, radical innovations occurs rather seldom . Development and implementation of radical innovations are complex, costly and risky processes. Examples on radical innovations are the electrification of Europe (Smith 2009:19) and wind power (Markard & Truffer 2006:616). The similarities with these technologies are that they demand a totally new system of infrastructure. New actors, new knowledge, new physical infrastructure and new regulations were crucial in order to develop and diffuse these technologies.

In addition to incremental and radical innovations, technology may also be classified as disruptive. A disruptive innovation “involves a replacement of existing norms of product design, performance attributes and production processes” (Smith 2009:18). Furthermore, they “result in worse product performance, at least in the near-term” (Christensen 2003:xv). Christensen consider the electric vehicle to be classified as a disruptive technology that has arisen out of the gasoline car. Due to its battery capacity, the electrical vehicle leads to worse product performance. While the product performance is worse, a disruptive innovation is on “a trajectory of improvement that might someday make them competitive in parts of the mainstream market"(Christensen 2003: 207). They also "bring to a market a very different value proposition than had been available previously" (Christensen 2003: xv). Christensen stresses that that technology of the electric vehicles is continuously improving and developing rapidly (Christensen 2003: 208). While the gasoline car is associated with freedom, electric vehicles are associated with "green values".

Electric cars require, like many other technologies, a particular infrastructure in order to diffuse. However, the technology does not demand a totally new system of infrastructure. It rather requires great changes in an already existing system that facilitates the gasoline car. Electric vehicles require different charging stations; both normal-, and fast charge stations. Payment- and communication solutions linked to charging stations are a part of the new demanded infrastructure. In this way, new value chains are required. However, electric vehicles do not call for new roads, new streetlights or new road signs, which are components of infrastructure already implemented and well established in society. Like the name illustrates, disruptive innovations, or at least electric vehicles, disrupt the already exciting system of infrastructure by requiring many changes in order to be diffused. This illustrates that the components within the road transport system are loosely coupled, something that has been supported by Markard (Markard 2010: 14). The components are not completely inseparable and it is possible to change one component without changing the rest.

Since disruptive innovations just require some changes in existing infrastructure, the investments cost for developing and implementing, are probably often lower when developing and implementing a completely new system. When only implementing some infrastructural components, due to lower investment costs, the government may not be an obviously owner.

Wooren et al. argues that when new technologies "depend on the availability of a physical infrastructure (that is incompatible with the existing infrastructure), overcoming lock-in is even more difficult" (Vooren et al. 2012: 100). Thus, since incremental innovations do not require a new infrastructure, overcoming lock-in of the existing technology will not be that hard. On the other hand, since radical innovations often demand a totally new system of infrastructure, overcoming the locked-in technology will be a challenge. Consequently, implementing radical innovations is a very difficult process.

Type of innovation:	Change in the system of infrastructure:	The difficulty of overcoming the exciting locked-in technology
Incremental	Incremental changes within the same system of infrastructure	Not that difficult
Disruptive	Replacing parts of the system of infrastructure, but the overall system	Quite difficult
Radical	Transforming the whole system of infrastructure	Very difficult

Table 3.1: Types of innovations and their requirements for infrastructure

3.5 Infrastructure and technological innovation systems

As aforementioned, in order to understand the dynamics of infrastructure, one has to bring in its soft sides. One way to do this is by examining development and diffusion of infrastructure through a systemic approach. It has recently been argued that it is of importance to understand infrastructure as a technological innovation system (Andersen & Wicken 2013:19). To approach the development and diffusion of an infrastructure in this way has, to my knowledge, not been done before. By using the framework of TIS one is able to understand infrastructure transformations in a broader context.

As already mentioned, a change towards electric mobility requires a change at three dimensions; at the supply side, at the demand side and at the infrastructure. To analyze the three dimensions within one technological innovation system is too complex to examine in one master thesis. However, since infrastructure binds the supply- and the demand side together, when focusing on this dimension, one will also gain a more generally understanding of electric mobility.

3.6 Summary

In this chapter the term “infrastructure” has been discussed. It has been argued that there is a need for a common understanding of the term. An understanding proposed in this chapter, has been to look at infrastructure as a physical artefact that unites the supply- and demand side. The thesis has also argued that it in order to understand the dynamic of infrastructure it is critical to understand it as a system, in which both physical and non-physical components are to be included. One way to do this is by looking at the infrastructure as a technological innovation system.

4.0 METHODOLOGY

4.1 Research design

The case was identified early in the research process. Although the research questions were not articulated before at a later stage of the research process, I knew that to point at barriers in the implementation of charging infrastructure in Norway was of interest for the thesis. With this in mind, relevant theoretical concepts and frameworks were identified. The framework of technological innovation system was considered to be of especial importance, while the concept of multi-level perspective was seen as valuable as a positioning tool. It became clear that there was a need for a theoretical discussion around infrastructure in a dynamic perspective. In order to identify the barriers in the process of development and diffusion of charging infrastructure in a satisfactory way, a deep and extensively study is required. With this in consideration I therefore argue that case study is the most appropriate methodology when conducting this study. Yin is arguing that if the research questions ”explain some present circumstance (…) the more that the case study method will be relevant” (Yin 2009: 4). Case study is also relevant when you are studying a social phenomenon extensively and deeply and where the researcher has no or little control (Yin 2009: 4). Implementation of charging infrastructure is a social phenomenon where the researcher has no control and hence, supports the use of case study. Later on in the process the research questions were articulated. After collecting data I found it appropriate to have two separate research questions. After I gained extended knowledge about Electric Mobility Norway it become clear that it would be suitable to present EMN as a possible “solution” to the weaknesses of the TIS. As a consequence, the empirical chapter is briefly divided into two interrelated parts

4.2 Collection of data

Interviews were the main source when obtaining data for the thesis. In addition, I also observed two partnership meetings at Electric Mobility Norway- in a total of twelve hours. Furthermore, document analysis was conducted. Pursuant to the time available

I consider I have collected relevant and various data for answering the research questions in a satisfactory way.

When doing good ethical research it is of importance to obtain consent from all the informants in the study. I contacted the management team in Electric Mobility Norway via email. Previous to the data collection I also met them in person. A formal contract was signed at their request. All the informants that were interviewed were as well contacted by email. The interviewees were asked to consent to the interview and a brief description of the study was provided. I also argued for why the specific organisation was of interest and relevance for the project. In this way I ensured that the informants had grounds for answering whether or not they wanted to contribute to the thesis.

4.2.1 Observations

Kearns argues that the data you collect by observations, may work as a compliment to more structural forms of data collection, such as interviews (Kearns 2010: 242). Through the observation I functioned as an "observer-as- participant" (Kearns 2010: 246). During the partnership meetings I was observing without directly participating. I did not interact, share my ideas or views regarding the business cluster. However, the informants were well aware that I was there observing. I presented myself and was sitting "around the table" like everybody else. In the breaks I mingled with the others. Because the informants knew that they were being observed, one can ask whether or not this influenced their behaviours at the meetings. There is, for instance, a chance that they tried to give a positive impression of the business cluster, put themselves in a better light. However, I did not get the impression that their behaviour where influenced considerably. One reason for this assumption is that during one of the partnership meetings the participants had a discussion on the functionality of the cluster. If they had wanted to make a positive impression of the cluster, they would probably have decided to have this discussion when I was not present. By observing I gained insight in how the actors interact and cooperate. I also gained an understanding of what worked well, and what were the shortcomings of the cluster. I believe that this understanding would be difficult to achieve if I interviewed the companies separately.

4.2.2 Interviews

Prior to collecting empirical data, a review of literature has been important. Based on the theories presented previously, the interview guides were created. The seven functions within a technological innovation system have been of especial importance. Many of the questions were asked to all informants, however some adjustments were made in order to fit the different interviewees.

A semi-structured approach was used when conducting the interviews. "This form of interviewing has some degree of predetermined order but maintains flexibility in the way issues are addressed by the informant" (Dunn 2010: 102). By using the semi-structured approach I had the possibility to ask follow-up questions if something was unclear or if I wanted the informant to elaborate. Before starting the interviews I notified the informants that the interviews were not strictly structured and that they had the possibility to bring up new topics and issues if desirable. All the informants accepted on being recorded as long as quotes were accepted before publishing. The audio recording made it easier for me focus on the informants instead of using time on taking notes. Consequently it also got easier to ask follow-up questions.

Date	Name	Position
05.08.13	Marianne Mølmen, Hans Cats	The county municipality of Oslo
07.08.13	Daniel Molin	The county municipality of Akershus
08.08.13	Petter Haugneland	Communication manager, The Norwegian EV association
12.08.13	Bjørn Trygve Hansen	Management team, Electric Mobility Norway
12.08.13	Leif Næss	Management team, Electric Mobility Norway

Table: 4.1- List of interviews

I conducted five interviews with six informants in total. Ideally, in order to gain a deeper understanding I would have included interviews with other significant actors. However, due to the restricted time limit in addition to the knowledge I gained through observation, it seemed as a good decision to confine myself to carry out five interviews. By interviewing only a restricted amount of actors I had the time to analyse the empirical findings in depth.

After I had gained an understanding of the industry I chose my informants based on whom I thought would give me relevant and useful information in order to be able to answer the research questions. The informants where selected with the aim of obtain various data. I assumed that the different interviewees would highlight the diverse aspects of the development and diffusion of the charging infrastructure.

I chose to interview the county municipalities in order to understand the development and diffusion of charging infrastructure from the aspects of public authorities. As the public authorities are not a homogeneous actor in regard to charging infrastructure I decided to interview both the county municipality of Oslo and Akershus. These two public actors have different strategies in relation to implementation of charging infrastructure.

Haugneland at the Norwegian EV-association was chosen as an interviewee because of their influential force and frequent interaction with public authorities and organizations within the industry. The Norwegian EV-association, which is a special interest organisation, is representing the EV-drivers. It was clear that The Norwegian EV-association possessed much knowledge that was essential for this study.

As understanding the role of Electric Mobility Norway is one of the aims for the thesis, it was obvious that the managers in EMN should be interviewed. I chose to interview two of the managers of EMN in order to gain as much data as possible. This turned out to be favourable, as different issues and dimensions were raised during the two interviews.

4.2.3 Document analysis

In addition to observations and interviews, I also conducted document analysis. The report “Sluttrapport for forretningsmodeller, avregnings- og betalingsløsninger” published by Grønn kontakt in 2013, has been of especial relevance to this study.

4.3 Validity and reliability

In order to achieve good research quality I have considered the requirements regarding reliability and validity during the research process. Yin emphasises three types of validity; internal-, external- and construct validity (Yin 2009). However, due to that this thesis is not a causal analysis, it does not make much sense to evaluate its internal validity.

4.3.1 Reliability

Reliability refers to whether a researcher which follows the same method as the previous researcher, will end up with the same findings and conclusions (Yin 2009: 45). However, in qualitative studies where people relate to each other, it is impossible to achieve absolutely reliability. The point is rather to "minimize the errors and biases in a study" (Yin 2009: 45). In this regard, it is important to illustrate the resource procedures. In order to achieve high reliability; my aim has been to be clear concerning the method and the research process. The interview guide, which has been the foundation for the collection of empirical data, is attached as an appendix. Before interviewing the informants I asked if they preferred to stay anonymous, which none of them wanted. Because there was no need to anonymise the informants, the research obtained a higher reliability. In order to obtain even higher reliability, transcriptions of the interviews could have been done. Because of restricted time it was decided to only write summaries of the interviews. However, the audio recordings are saved in a case study database folder, which are available on request.

4.3.2 Construct validity

When having achieved good construct validity you have been able developing a sufficient set of measures in order to approach the case you are studying. In order to meet the requirements of good construct validity one can use several sources of evidence (Yin 2009: 42), something that has been done by collecting data through interviewing different persons, observations, and documentary analysis. In order to achieve higher construct validity I could have let the informants read and accept the transcriptions of the interviews. As argued above, transcriptions where not made due to the restricted amount of time. Instead, the quotes were sent to the informants for approval before publishing them in the thesis.

4.3.3 External validity

External validity is about whether the study is generalizable. Even though this is a case study it does not have a statistical generalization (Yin 2009: 43). The study addresses development and diffusion of charging infrastructure in a specific context in the southeast part of Norway. Since the empirical findings are analysed through the framework of technological innovation system one can argue that the study is analytical generalisable. The aim of this study is not to generalize its findings, but to contribute to expand the theories about the dynamics of infrastructure and the framework of technological innovation systems.

5.0 EMPRICAL FINDINGS AND DISCUSSION

By using the framework of technological innovation system, the challenges regarding development and diffusion of charging infrastructure will be identified, discussed and reflected upon. In the second part of the chapter it will be analyzed which contribution the business cluster Electric Mobility Norway is playing in this regard.

5.1 Charging infrastructure

> EV charging infrastructure: is composed of one or several EV charging points and their connections to the distribution grid, i.e. Electric Vehicle Supply Equipment (EVSE). In some cases, additional equipment such as transformers, generators or storage devices can be part of the EV infrastructure in order to provide a reliable service (Román et al. 2011:6363)

In line with the theory introduced in chapter 3, payment-, IT- and communication-solutions, which are linked to the chargers, are also part of the charging infrastructure.

Implementation of charging infrastructure in Oslo and its surroundings
Charging stations can either be implemented on public ground where it is publicly accessible, or it can be implemented on private property and be either privately or publicly accessible (Román et al. 2011: 6362). For instance, the chargers may be implemented along public roads, in private garages or at commercial buildings. In Norway, April 2013, it existed 4 029 normal charger- and 127 fast charger point, all publicly accessible. In addition, there are charging points which are private accessible, implemented at the EV-driver’s property. A great proportion of these chargers where implemented in the southeast part of Norway. Asker is the place in Norway with the most EV-drivers per capita. In 2012 there were 1 506 inhabitants per charging point. In comparison, in Oslo, with less EV- density, had in 2012 only 712 inhabitants per charging point. (Figenbaum & Amundsen 2013, & Vethe, 2011). These numbers illustrate the differences in accessibility of chargers in the different municipalities.

The duration of charging an electric vehicle at a normal charger is considered to be between six and eight hours (Figenbaum and Amundsen,2013). Since the charging time is relatively long, it is most appropriate to use this type of charger when the car is staying parked for a longer period of time. In Norway, the daily average mileage for cars is 48,5 kilometre, which means that it is usually sufficient to use normal chargers (Civitas 2012: 42). To charge a car with a fast charger takes between 20 to 30 minutes (Figenbaum & Amundsen, 2013) and hence, reduces the range disadvantage of the electric vehicle. When running out of electricity, the fast charger works almost as a gasoline pump, charging the car in a relatively short period of time. This may be necessarily, not only when one havs planned to drive long distances, but also if something unforeseen occurs, as for instance a queue or a diversion (Civitas 2012: 56).

In Norway it is suitable to charge cars outside the owner's home due to the cold climate. As there often is a need for block heater at wintertime, electric plugs are normally already wired. When implementing chargers on private grounds, the owner of the house and the car will need to pay for the infrastructure, which consists of an EV connector and a connection cable (Román et al. 2011: 6365). However, to have a large roll-out on pubic ground involves risk and requires considerable expenditure (Román et al. 2011: 6362). The costs of developing and implementing charging infrastructure varies in relation to local conditions. To develop a normal charging station that facilitates two charging points cost approximately 11 500 Norwegian kroner. The actual installation constitutes the largest cost. Thereby, the total expenditures are normally between 50'- 100 000 Norwegian kroner (between 6 200-12 500 Euros) (Civitas 2012: 49). Furthermore, the cost of developing and implementing a fast-charger, which facilitates two charging points, is estimated to be at least 1 million Norwegian kroner (around 124 600 Euros) (Civitas 2012: 58)

5.2 Analysing the TIS of charging infrastructure

When using a technological innovation system approach, one has to decide how to delimit the system. It is essential to define the geographical boundaries and choose if you want to define the technology as a particular product/artefact or as a knowledge field (Carlsson et al. 2002: 233- 237). This thesis will provide an analysis based on looking at charging infrastructure as an artefact. The system will be delimited to Oslo and its surrounding areas, in the southeast part of Norway.

5.2.1 The structural components

As elaborated on in the theory chapter, after defining the boundaries of the TIS, one has to identify its structural components, these being actors, networks and institutions. These components will be introduced in the following section.

Actors

Some of the actors in the TIS can be identified through examination of the value chain for charging infrastructure. The actors in the value chain has been identified based on what has been presented in section 5.1

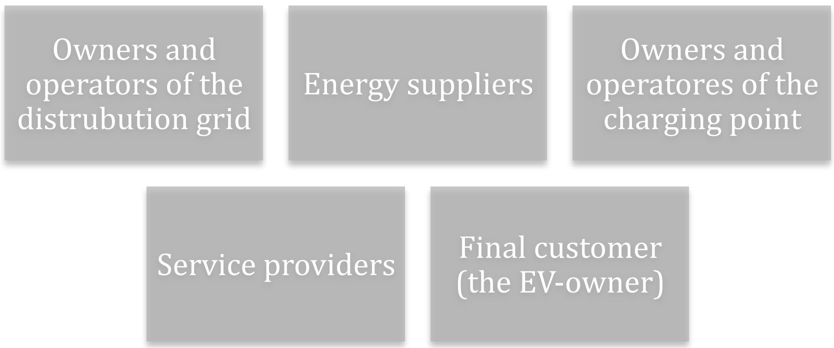

Figure 5.1- Groups of actors along the value chain

The value chain contains both old actors that are well established in the electric power system, in addition to new actors. Firstly, Haflsund is currently the largest owner and operator of the distribution grid in the southeast part of Norway (Hafslund.no). When implementing a charging infrastructure, one need to connect the charging point to the distribution grid in order to get electricity. This requires available capacity on the grid. Energy suppliers, for instance companies such as Norges Energi and Fjordkraft, are connected between the distribution grid and the charging point and are the companies selling the electricity. Furthermore, the suppliers of charging infrastructure origin from various industries, however, the companies in the energy industry are the leading ones (Energi i Norge, 2009). Some of the most experienced providers of charging infrastructure are the companies ABB, Enesto, Infratek, EV Power and Fortum (ladestasjoner.no).

The charging points located outside a private house or in a private garage belong to the owner of the property. However, the ownership of charging stations that are public accessible is currently fragmented. Many actors only own a small number of chargers. The owners are both from the public- and the private sector and are equal to the developers, from various industries. The government has decided that private actors are going to develop and operate the charging infrastructure (Grønn kontakt 2013:6). Nevertheless, the municipality of Oslo has the main ownership of normal chargers in Norway (Frydenlund 2013). Examples of other owners of normal chargers are for instance housing cooperatives, parking companies and private companies that want to provide charging for their customers and employees (Transnova 2012 :20). Furthermore, it is often that the companies that provide the fast chargers own them. “Energiselskapet Buskerud” is an example (Energi i Norge, 2010). The public sector also own a few fast chargers, such as the municipality of Bærum that has the ownership of two fast chargers (Ringvold, 2013).

Actors providing services, such as payment- and communication solutions, are also often suppliers of the infrastructure. Grønn kontakt and Fortum are examples of companies that both provide payment solutions as well as operating charging stations. Nevertheless, status quo is that many owners of charging infrastructure do not invest in any payment solutions, hence, charging stations are free to use for the customers.

Based on what is illustrated above, the value chain is today characterized by many small-scale owners, which instead of being specialized to one part of the value chain, are related to many. Hence, the different actors and their roles in the value chain are not as separated in reality, as what are illustrated in table 5.2

As previously mentioned, the partners of “Electric Mobility Norway” are from different industries. Many of these companies contribute the different components in the value chain for charging infrastructure identified above.

Companies of EMN:	Industry/ core activities
Kongsberg Automotive	Producer of components and system solutions in the car industry
Kongsberg Gruppen	Systems solution within defense, maritime and offshore
Eltek	Power electronics
Energiselskapet Buskerud	Energy industry
Devotek	Mechanics, electronics, sensors, software
Infratek	Developing and drifting "critical infrastructure"
Sintef	R&D institution
Norpart	An industry community for companies in the car industry
ITS Norge	ITS (Intelligent Transport Systems)
Grønn kontakt	Consists of 23 companies in the energy industry
Q-free	I.e. developing solutions for road user charging
Move About	Drifting an EV- fleet
Høyskolen i Buskerud	R&D institution

Table: 5.2 – Members of Electric Mobility Norway

There are also other actors of great importance to the system that are not directly related to the value chain. The special interests organizations "The Norwegian EV-association" and the organizations named "Green car" have big influence on the system. In addition, Norwegian authorities are also of great importance. The

Norwegian government, the county municipalities and the municipalities within the counties are vital. In addition to that some of them are owners of charging infrastructure, the Norwegian authorities, together with Transnova, can be understood as policymakers and actors that provide support to the development and the implementation of charging stations. Furthermore, the users of the charging stations (the EV-drivers) are also of importance. The groups of actors identified above are all, in various ways, influencing to development and diffusion of charging infrastructure in the area of Oslo and its surroundings.

Networks

As already mentioned in section 2.2, within a technological innovation system there are various types of networks. In learning networks, knowledge is being exchanged between the different actors. In the TIS of charging infrastructure, both formal and informal learning networks are present. Electric Mobility Norway can be understood as a formal learning network. The members of the cluster that contributes to the different parts of the value chain hold different types of knowledge. This knowledge is being shared within the business cluster. In addition, knowledge between the actors in the system is being shared in a more informal way, without being part of a formal network. For instance, the county municipalities of Oslo and Akershus, as well as the EV-association, are to some extent interacting and sharing experiences. The diffusion of knowledge within the TIS will be elaborated in section 5.2.1

Institutions

Institutions refer to factors such as regulations, laws, norms and culture, and are defining the framework conditions for innovation activities. In addition, they also influence the interactions between the actors. The Norwegian authorities have in accordance with the European Union Directive committed to reduce their emissions of greenhouse gases with 30 percent by 2020. Furthermore, they have committed to be totally carbon neutral by the year of 2050. In this regard, incentives linked to charging infrastructure have been established. For instance, it is free to park when charging electric vehicles. In addition, one also receive financial support when developing infrastructure when supplying public accessible infrastructure. Today it is free to charge an electric car. This is not an incentive but rather a consequence of payment solutions being more expensive to implement than it is to pay for the electricity (Figenbaum & Amundsen, 2013). In addition to incentives that are directly linked to the charging infrastructure, there has been established several incentives in order to make the electric car more competitive. For example, the vehicles are allowed to drive in the bus lines and also have free municipal parking. They are exempted from road taxes, toll payments and normal purchase taxes, which for ordinary cars are extremely high in Norway (Avere, 2012). These incentives are of big importance for the TIS, although they are not directly linked to charging infrastructure. An increase in demand for electric vehicles will lead to an increase in demand for charging infrastructure.

The interaction between actors, networks and institutions generate the dynamics within the technological innovation system. Through analyzing the different functions of the TIS (see section 2.2.1) the present dynamics within the system will be discovered and further discussed.

5.2.2 Knowledge development and knowledge diffusion

As previously elaborated on, knowledge development and knowledge diffusion are decisive activities within a technological innovation system.

Although there is much scientific research on electric mobility in general (for instance the institute of transport economics), it seems to be minimal research focusing particularly on charging infrastructure in Oslo and its surroundings. Universities and other R&D institutions play a limited role regarding creation of knowledge. When considering the amount of research being performed in regard to infrastructure, Molin compares Norway with its neighbour countries and states: “There is no doubt that there is a great need for knowledge (…) there is very little systematic research"(Daniel Molin, the county municipality of Akershus).

Due to the limited research on the system, the knowledge creation is considered to be of informal nature. Much of the system’s knowledge creation occurs when learning from earlier experiences; “learning by doing”. When discussing development and diffusion of charging infrastructure, Mølmen argues: “ I've been working with it for five years now, so I feel that I start to learn more (...) It has been like this; you learn along the way”(Møllem, the county municipality of Oslo).

The interviews indicated that the knowledge to some extent is diffused between the actors. The county municipalities of Oslo and Akershus are exchanging knowledge and experiences informally. Under extraordinary circumstances the actors applies to the special interest organizations, which acts as an adviser holding expert knowledge. Electric Mobility Norway function as an arena where the members of the cluster share firm-specific knowledge. This way, new knowledge becomes diffused across industries and new combinations of existing knowledge can develop. The diffusion and creation of knowledge in the system is essential for innovation activities and the system as a whole.

In order to ensure further development of the system, new knowledge needs to be created. There is a lack of knowledge in regard to commercialisation of the charging infrastructure. Currently, the charging infrastructure is mainly free to use. As previously mentioned, due to the ownership of charging infrastructure being fragmented, investing in payment solutions is more resource demanding than actually paying the electricity for the users. This is not sustainable over time. In order to make new actors entering the system, one has to commercialise the charging infrastructure. Today, there is much uncertainty regarding the payment solutions, customer behaviour and their willingness to pay for the charging infrastructure. In order for the technological innovation system to evolve it is critical to gain knowledge in such areas.

5.2.3 Entrepreneurial experimentation

"Due to the rapid development, it is limited how much you actually know (…) It's hard to know how it will function until it actually get implemented" (Mølmen, the county council of Oslo)

Charging infrastructure consists of immature technologies that are neither greatly diffused nor established in society. As previously stated, the southeast part of Norway is the place in the world with most electric vehicles per capita. The actors are therefore not able to gain sufficient knowledge due to the lack of opportunities of examining and imitating experienced other actors. Thus, in order to develop the innovation system further, entrepreneurial experimentation is crucial.

There is relatively much experimentation carried out in the system. A new infrastructure has gradually been implemented in society despite limited knowledge concerning the technology and the market. The county municipality of Oslo implemented charging infrastructure in the city without possessing much knowledge regarding the technology in a social context. For instance, little was known about the amount of charging stations, and what kind of chargers that would be suitable to implement in Oslo. Mølmen and Cats argue that the final decision to implement 400 charging stations in Oslo was quite arbitrary, as it also was proposed to implement 1000 chargers. Furthermore, after the implementation, many of the charging stations were run down by cars and broke as a result of this. As a consequence, the charging stations were adjusted. The new type of charging stations was designed for such incidences and had a green light that made them more visible. Hence, a learning process occurred during the experimentation. As a result more customized and functional products were developed and implemented.

Although there has been a lot of experimentation, due to the immatureness and lack of experiences with the charging infrastructure, there is still a need for further experimentation in the system. There is especially need for experimentation linked to the implementation of payment solutions. As mentioned above, it lacks much essential knowledge regarding the commercialization of the charging infrastructure. In order gain indispensable knowledge there is a great need for carry out pilot projects in the field.

5.2.3 Influence the direction of search

As previously elaborated on, the Norwegian government has established incentives in order to create a demand for charging infrastructure and electric cars. It is clear that the incentives have created a market for charging infrastructure. Economic reasons are the biggest motivations for the EV-drivers to buy electric vehicles. A survey done by the Norwegian EV- association found that to save money is by far the biggest reason for why people choose to buy electric vehicles, while “save the environment” and “save time” is less decisive reasons. The demand created by the Norwegian government is probably a crucial factor for companies entering the system.

While conducting the interviews, it became clear that the global climate challenge is not the main motivation for actors to invest in charging infrastructure. All the informants from the county municipalities emphasised the fact that a shift from gasoline cars to electric vehicles would lead to an improvement of the urban environment. Charging infrastructure is facilitating this shift. The motivation of the county municipalities was to reduce the noise and local air pollution. Both Næss and Hansen in the executive team of Electric Mobility Norway emphasis the excitement of working in an immature industry, as it creates great business opportunities. A motivation for the members being a part of the EMN-cluster is their abilities to create and share knowledge, under the belief that this may lead to a future competitive advantage.

The charging infrastructure is not yet commercialized in Norway. As a consequence of this, there is no return on investments (Grønn kontakt: 2013: 20). This is obviously influencing the actors when they consider entering the system. As long as the infrastructure is not commercialised, this will restrain further development and diffusion of charging infrastructure. There is clearly a great need for more incentives that will increase the commercial drivers in the system.

5.2.4 Market formation

When drivers buy electric vehicles they are also articulating a demand for its infrastructure. As previously mentioned, the southeast part of Norway has the highest EV-density in the world, with its 2,9 percent of the total market share of passenger cars in Norway (Kvisle[2], 2013). As mentioned in section 1.1 this number is increasing rapidly. The same applies to the market related to charging infrastructure. Every autumn, the county municipality of Oslo conduct an analysis in order to find out how much charging infrastructure is used. The analysis shows that the use of charging points has increased significantly, both during day- and nighttimes. Almost 70 percent of the today’s charger points are used at daytime, while approximately 40 percent of the charging points are used at night.

Due to the lack of commercialisation and no return on investments, one can argue that even though the market potential is big, one is not able to exploit it.

There is also much uncertainty related to further development of the market. As mentioned in section 1.1 the market of electric vehicles is increasing rapidly. If this trend continues, a mass market of charging infrastructure and electric vehicles may be reached in near future. However, it is possible that it is too optimistic to assume that the market will grow as rapidly as previous years. Haugneland argues that predictable conditions are essential in order to ensure further growth in the market. Currently it exists several incentives that make the electric vehicle competitive as a means of transport (see section 5.2). In a few years, these incentives and regulations are going to be reconsidered (Avere, 2012), hence, the conditions are thereby not predictable, something that cause uncertainty in the market. Haugneland states ”Of course there are many people not buying electric cars due to the uncertainty” (Haugneland, Norwegian EV-foundation). The uncertainty that defines the market is reflected in a member survey done by the EV-association; 91 percent answered that they were truly satisfied being users of an electric vehicle. On the contrary, only 64 percent of the EV-drivers were convinced that their next car was going to be an electric vehicle. As a consequence of the uncertainty regarding the further development of the market, there is also uncertainty considering the market for charging infrastructure.

5.2.5 Legitimation

The degree of social acceptance of charging infrastructure is highly depending on the legitimation of electric vehicles. In comparison with what often is the case with new technologies, charging infrastructure can be considered as fairly legitimated by multiple actors.

The incentives that the Norwegian government has introduced in order to diffuse electric mobility, shows that the electric vehicle and the charging infrastructure are desired by official authorities. In light of the empirical findings one can argue that the county municipalities have accepted the charging infrastructure to a certain degree. Molin states that the county municipality of Akershus wants the infrastructure to work as an incentive rather than a barrier for diffusion of electric vehicles. As previously mentioned, the county municipality of Oslo is the largest owner of the charging infrastructure in Norway. Furthermore, both the county municipalities of Oslo and Akershus provide financial support for private actors (e.g. shopping centres or housing cooperatives) that wish to implement charging stations at their private properties.

Nevertheless, official authorities are yet to fully legitimate charging infrastructure and electric mobility. Cats argues: ”We see that the sales of electric cars are increasing continuously. It is limited with space on the roads. Our purpose is not to make people drive all the way into the city centre” (Cats, the county municipality of Oslo). Furthermore, Mølmen questions whether it is best to dedicate an available area on cycle lanes or to extent the pavements instead of use it on a charging station. It seems like their attitudes are dual. Due to demographic grow in the southeast part of Norway, it will not be sufficient space on the roads for all people to drive individual means of transport. In this regard, implementing charging infrastructure is not a solution to such a problem. Ideally it would be more preferable if people used public transportation, cycled or walked instead of separately driving electric vehicles.

It appears that the charging infrastructure have been socially accepted by the inhabitants of Oslo. Møllem and Cats tell that when they started implementing charging stations, they were worried that people would complain. Much of the parking spaces that before were available for all types of cars, are now reserved for electrical vehicles only, and hence, fewer parking spaces were available for people driving gasoline cars. However, they have so far only received one complaint, which may indicate that the charging infrastructure now is socially accepted, both by users and non-users of the electrical vehicle.

5.2.6 Resource mobilisation

The county municipality of Oslo and Akershus argue that they do not consider economic factors to be a significant barrier for diffusion of the charging infrastructure in their municipalities. The politicians have prioritised the field and are thereby mobilising financial resources. The county municipality of Oslo has been able to implement 490 charging points under its own auspices. In comparison, the county municipality of Akershus does not own any of the publicly accessible charging stations, but has, in similarity to Oslo, established a system for subsidies. Here, persons that wish to implement charging infrastructure, for instance the municipalities, parking companies or housing cooperatives, can apply to receive financial support. Molin argues that based on the response he has received, financial resources do not seem to be a sufficient barrier for diffusion of charging infrastructure. Nevertheless, he believes that the municipalities in Akershus experience uncertainty regarding investments in charging infrastructure. Currently, just a few municipalities have implemented chargers under its own auspices. If more financial resources were earmarked the municipalities, this would probably reduce the uncertainty, and hence, make the municipalities more willing to invest in charging infrastructure.

Haugneland in the EV-association stresses that the Norwegian authorities should increase the financial support for private actors that wish to invest in infrastructure. Today, the authorities have decided to support up to 45 percent of the total costs in regard to the development of charging stations. The subsidies will be provided until the market has reached a critical mass. Furthermore, the financial support that companies may receive is not sufficient to make them invest in the industry (Grønn kontakt: 2013: 15). There is therefore a need that official authorities mobilise more financial support for private actors considering development and operation of the charging stations.

The management team in Electric Mobility Norway is satisfied with the amount of finical funding they have received from official authorities. For EMN, financial resources are currently not a barrier for further development of the business cluster. However, it has been stated that EMN will require more financial resources in the future as they wish to establish a test arena that will demand resources and require financial support.

Cats states: “Money has not been a barrier for implementing the chargers, so I do not consider money as a problem. A bigger problem is that we are not many people working with this" (Hans, The county municipality of Oslo). He further says that few people have knowledge about implementation of charging infrastructure. When asked if the county municipality of Akershus are collecting data on the already existing infrastructure Molin says: "No, we do not do that, well, we are doing it indirectly, but we do not have the capacity to analyse it" (Molin: The county municipality of Akershus). In light of the collected data, one may argue that human resources are a shortcoming in the county municipalities. One of the challenges is to find qualified employees with knowledge about electric mobility and charging infrastructure. People with such knowledge seem to be almost non-existing. As previously elaborated on, knowledge is gained through experimentation and "learning by doing". To mobilise human resources in such ways is probably resource demanding, especially in terms of time.

5.2.7 Development of positive externalities

There are few actors engaging in electric mobility and charging infrastructure at the southeast part of Norway. The milieu is small and that the actors know each other. Nevertheless, it has been argued that the industry today is in a growth-phase, and that new actors are continually entering.

In order to make a shift from gasoline cars to electric vehicles, more actors need to enter the industry. Hansen argues that many of the firms in EMN are more active within the field of electric mobility than before they entered the cluster. The objective of EMN is to help the cluster-members to take the risk and "walk into the unknown". Hence, one can say that EMN contributing with attracting actors to the industry, which will be favourable for the system as a whole. By bringing in new actors, positive externalities can be developed. The different externalities the business cluster EMN generates will be elaborated on in section 5.3.

5.3 Blocking mechanisms

Due to the empirical findings two groups of internal blocking mechanisms can be identified. When analysing the empirical data, it become clear that there is a lack in cooperation between the actors and that big uncertainty is characterising the system.

Unless the interaction does not improve and the uncertainty is not reduced, these factors will obstruct the further development of the system.

5.3.1 Weak interaction

There is a need for closer interaction between the different actors in the system. As previously elaborated on in the third chapter, in order to implement charging infrastructure, a systemic change is needed. Although a disruptive innovation does not require a totally new system of infrastructure in order to be diffused, just the replacement of certain infrastructural parts of an already existed system, one can still argue that it is a complex act. This requires involvement and cooperation from multiple actors.

In order to develop and diffuse charging infrastructure the actors need to cooperate and work more or less in the same direction. This might be difficult due to their different roles, interests and motivations. Hansen states: "There are so many actors that have to agree on this as something we are going to do (…) It will not help if only some of the actors take initiative"(Hansen, EMN). He continues: "To coordinate all the required actors, to get them all to pull in more or less the same direction, is probably the greatest barrier" (Hansen, EMN).

It may seem like private and public actors have incompatible interests. Haugneland argues that the suppliers want to sell their most sophisticated technological solutions to get as high profit as possible. However, complex technological solutions are not what that the EV- association necessarily needs. Contrarily to the private actors, the EV-association is not driven by profit but acts on behalf of the users. For instance, while the suppliers want to develop sophisticated "smart phone apps", the EV-association may prefer card payments as the favourable payment solution. Haugneland states that since the EV-drivers have to deal with new technology when driving the electrical vehicle, it is not necessarily in their best interest to make them deal with even more new complex technologies linked to the infrastructure. Furthermore, Molin stresses that in the process of commercialising the charging infrastructure, it is important to standardise the payment solutions in order to make it easier for the users. For this to be conducted, excellent interactions between the actors are crucial. So far, there has not been any solution to this issue. If the actors within the system cannot agree to find a middle course between the interest of private actors and the potential users, this might obstruct the market formation or new firms entering the system.

Definition of roles

Based on the empirical findings one may argue that the system is in a formative stage. It seems that the actors do not know their roles and specific tasks in relation to the other actors within the evolving system. There is no written agreement or consensus between the actors regarding who is responsible for developing and diffusing the charging infrastructure. Hansen stresses: "the public and the private need to define their roles (…) the distribution of roles should be discussed" (Hansen, EMN).

As previously elaborated on, the county municipality of Oslo owns all normal chargers implemented in the public areas in Oslo. Contrarily, the county municipality of Akershus do not own or operate anyone. The explanation may be that Oslo is both a county and a municipality, while the county of Akershus consists of 22 municipalities. However, Molin states that there are no agreements concerning whether the municipalities are responsible for owning and operating the charging infrastructure in their area. Although the municipality of Bærum owns many normal- and fast chargers, this is not the case with other municipalities in Akershus. Even though Oslo owns and operates normal chargers, they have deliberately refused owning fast chargers. By investing in fast chargers they are afraid that the willingness to invest for private actors will decrease, as they are not able to set a competitive price, which they acknowledge would be unfortunate for the further growth of the industry.

Since it has been officially decided that private actors are going to develop and operate the charging infrastructure, one need to discuss who are to take the responsibility for this. Hansen asks "are there the energy companies, the gas station chains (…) the parking companies or the totally new actors? They are all scratching their heads"(Hansen, EMN). A possible consequence of the ambiguity of the role division is that potential new actors may be reluctant to enter the system, which is considered to be unfavourable. Lack of new actors entering the system will lead to an absence of the creation of positive externalities, something that will result in a slow development of the system. For instance, one can imagine that without new actors entering the system, the processes of knowledge creation and entrepreneurial experimentation will develop slower, or at worst stagnate. It will then be difficult for the system to move from a formative- to a mature stage. Extensive cooperation between the actors is therefore crucial for the system in order to evolve.

5.3.2 Great uncertainty

The actors within the innovation system experience uncertainty in different ways. The southeast part of Norway is world leading in use of electric cars. It is therefore hard for the actors to gain experiences and obtain knowledge from elsewhere. The municipalities experience uncertainty in the process of implementation of the charging infrastructure. “The uncertainty is enormous. Since we are managing public money, we cannot go out as crazy” (Molin, the county municipality of Akershus). He further states that the different municipalities in Akershus already are affected by uncertainty and hence, are reluctant to invest in charging infrastructure as it generates even more uncertainty.

As illustrated above, there is much uncertainty regarding the development of the market. Haugneland argues that due to unpredictable framework conditions, many potential users decide not to buy an electric vehicle. It is difficult to predict what will happen in the market if the incentives disappear and whether or not the electric vehicle still will be seen as an attractive alternative to the gasoline car. Furthermore, there is much uncertainty considering the commercialization of the market. Today the charging infrastructure is usually free for the users, and there is little information concerning customer behaviour and their willingness to pay for the infrastructure in the future. The combination of high establishment costs and much uncertainty in the market, makes it risky for private actors to invest in charging infrastructure.

Furthermore, one can assume that much uncertainty will slow down the market formation. Since actors perceive investments in charging infrastructure to be risky, potential actors can decide not to enter the industry. As illustrated above, this will be unfortunate for the development of the system, and hence the development and diffusion of the infrastructure.

5.4 The potential role of Electric Mobility Norway

How is Electric Mobility Norway contributing in order to develop and diffuse charging infrastructure in Oslo and its surroundings?

EMN wish to develop products linked to charging infrastructure by looking further than today's "typical charging infrastructure". Hansen stresses: "One has to look beyond the fast-chargers. That is not the only solution"(Hansen EMN). He continues: "If we are going to make a big boost in the infrastructure for electric cars, I think we have to implement IT- or communication solutions. Then vehicles can be connected to the network of roads and the electricity grid, so much of the planning can be eliminated for the user"(Hansen, EMN). Hansen feels that the bureaucratic system, public and private actors are locked-in to the existing system where one thinks of charging infrastructure like it is a gasoline pump. He hopes that EMN, by the virtue of being a cluster, can push for a new way of thinking.

It is clear regard to development and diffusion of infrastructure, it is clear that EMN has the potential to play a vital role, as the cluster can contribute positively on the weaknesses of the system. As illustrated above, EMN contributes to bring in actors from various industries in to the technological innovation system. This leads to a creation of positive externalities; by the virtue of being a cluster it has the potential to reduce the system's two blocking mechanisms, lack of cooperation and uncertainty, which is going to be elaborated on in the following sections.

5.4.1 Facilitating interaction and cooperation

As illustrated above, there is a lack of cooperation between the actors in the system that leads to a decrease in the processes of development and diffusion of charging infrastructure. Collaboration between actors, especially between the private and the public, needs to be improved. In EMN, both private and public actors are members of the business cluster. In addition to the actors that are formal members, they do also interact with other actors, as for instance different public authorities such as the municipalities. EMN facilitates meeting places where the different actors, both private and public, can gather to discuss the development and diffusion of infrastructure. For example, the 5th of September 2013, EMN arranged a workshop related to electric mobility. They invited relevant actors, both from private and public sector, with the purpose of creating common perspectives for the future. Their ambition was to set the foundation for future collaboration projects, involving both EMN- and non-EMN members.

Hansen explains “ We want a collaboration that can break down the barriers that exists between the private and the public and to discuss new solutions based on needs and opportunities” (Hansen, EMN). He emphasises that it may be difficult for individual firms to cooperate with public actors. By working together in a cluster, the interaction between the private and the public may become simpler.

Hence, one can understand EMN as a business cluster that facilitates interaction and cooperation between public authorities and private actors across core activities. As already elaborated on, little interaction is preventing the development of the system. The fact that EMN is facilitating cooperation is therefore considered as positive. In this way, EMN is an important actor in the system.

5.4.2 Reduce the uncertainty

When investing in infrastructure one has to manage high investment costs. This might be considered as a risky action, and especially without knowing how much return on investment one might expect. Næss argues that the intention of EMN is to encourage the firms in the cluster to take risks. He believes that it will, by the virtue of being a cluster, be formed a collective thinking that convince the actors to take risks and invest in electric mobility. However, EMN is not only facilitating a reduction in uncertainty for the actors formally engaged in the cluster. EMN has also the potential to reduce the uncertainty generally in the TIS.

Test-arena- creation of knowledge

EMN is about to establish a test-arena, where their products and solutions will be tested in a real world setting, in the region Oslo to Kongsberg, before implemented in society. This test-arena is assumed to reduce uncertainty. Hansen stresses that in order to meet the market demand one has to be in proximity to the customers. Through a test-arena the companies will be able to test out their products in a real market. As illustrated in section 3.1.1, infrastructure needs to facilitate the demand side. However, currently many aspects are still unknown regarding the market. By establishing a test-arena the companies within EMN will be able to gain knowledge about the customer, which may lead to improved and more suitable products and solutions. Næss states that they, through the test-arena, are able to test payment solutions and find customers' willingness to pay. Thus, more knowledge concerning the commercialisation process in the charging infrastructure will be achieved.

To establish a test-arena is not advantageous solely for the members of EMN, as it probably leads to a reduction of uncertainty for non-members of the cluster. Through the test-arena EMN will gain market insight, which will be valuable knowledge for the system as a whole. When asking Hansen if he think EMN contributes to the industry he answers "(…) through representing a milieu of competence, I believe we will have an indirect effect that will be available for the public and others" (Hansen, EMN).

As an establishment of a test arena is very resource demanding, this is something the members of the cluster would not be able to achieve individually. By gathering together in a cluster, valuable market insight can be achieved. EMN will therefore work as a knowledge creator, bringing in new knowledge to the system. In this sense, the cluster will strengthen the system's function of "knowledge development and diffusion", and hence reduce uncertainty, which probably will lead to a greater willingness for firms to enter the industry. The knowledge creation will probably also lead to benefits for the users, as it paves the way for the development of more market suitable products.

5.5 Summary

By using a technological innovation system approach, one has been able to grasp the dynamics of charging infrastructure, which has been crucial in order to answer this thesis's research questions. After analysing the development and diffusion of the charging infrastructure in Oslo and its surroundings as a TIS, barriers in the innovation processes have been identified. There is too little interaction and cooperation between the actors within the system. Furthermore, there is no agreement which actor is responsible for the development and diffusion of charging infrastructure; hence, there is a need for clarification. As the innovation system is characterized by uncertainty, it has been argued that limited cooperation and much uncertainty are unfortunate for the development and implementation of infrastructure.

Furthermore, it has become clear that EMN, by virtue of being a cluster, have the opportunity to strengthen the technological innovation system in multiple ways. By creation of knowledge and facilitating an arena of interaction, one may achieve a reduction in uncertainty and an increase in cooperation between the actors. Thus, it is apparent that EMN has the potential, and already plays a vital role in order to implement infrastructure in the southeast part of Norway.

Although the analysis identifies Electric Mobility Norway as an important actor that contributes positively to the system's weaknesses, it is of importance to highlight that the business cluster is at a formative stage. Although there are tangible plans, there has not yet been conducted a test-arena. Furthermore, we do not know the results of such a project before it actually has been performed. Hence, this thesis does not evaluate the currently role of EMN, but examines its potential future position. Whether or not EMN will exploit its potential is impossible to know without performing a retro perspective analysis. However, this study has showed that EMN, in the virtue of being a cluster, have the potential to reduce uncertainty and facilitate corporation; something that would be difficult if the members of EMN were to operate individually.

5.6 Policy advices

Through the analysis it became clear that the TIS is in many ways in a formative stage. In order to move to a mature stage a clear strategy needs to be developed, communicated and followed by the actors in the system. Although it is decided that the charging infrastructure is to be commercialised, the county municipality of Oslo is currently its biggest owner. As the public authorities have been responsible for implementing charging stations in Oslo, many charging points have been implemented. In other areas where the public has left the responsibility to private actors, charging infrastructure is often less diffused. The current lack in a clear overall strategy creates uncertainty and a particular need for cooperation, which again slows down the development of the system. In light of the findings in this study, there is a need for clarifying the overall strategy regarding development and diffusion of charging infrastructure. If private actors are to have the responsibility for the diffusion of charging stations, there is a need for more mobilisations of financial resources, making private actors willing to invest. If public authorities are going to have the responsibility, there is a need for some type of governmental regulations, pushing the municipalities to invest in charging infrastructure. Findings indicate that, until it has been developed, expressed and followed a clear overall strategy, establishments of business clusters like EMN is of high importance.

One can ask oneself whether these findings are transferable to other similar contexts. In the theory chapter it was argued that disruptive technologies do not require a totally new system of infrastructure, but only some new infrastructural components (see section 3.4). The development- and implementation costs are in these situations often less than what usually is the case when developing a whole system of infrastructure. Confusion of who that actually is going to be responsible for the infrastructure will likely occur. In such cases cooperation between the actors is of especial importance. In order to map whether or not these assumptions are correct, further research is required.

6.0 CONCLUDING REMARKS

We are today locked into a hydrocarbon regime, where fossil fuel based technologies are widely used. However, the regime is currently under pressure as the world is facing a climate challenge and niches hosting environmental friendly technologies are emerging. The demand for electric vehicles is rapidly increasing, which generate a need for charging infrastructure. Although much has happened in the development and the diffusion of the charging infrastructure in Oslo and its surroundings, uncertainty and limited cooperation between the different actors are currently slowing down the processes. The business cluster Electric Mobility Norway has the potential to contribute positively where the system has its shortcomings. In the virtue of being a cluster, EMN has the opportunity to reduce the uncertainty and facilitate an arena where actors interact and cooperate.

This study has its limitations. More empirical data could have been collected in order to increase the quality of the study. A restricted collection of empirical data leads to a more limited understanding of the field, which of course is unfortunately. However, an extended collection of data was difficult due to the circumstances of this thesis. Furthermore, when analysing the empirical data through the seven functions in the framework of technological innovation system one gains a limited understanding of the field. Analysing only one of the functions could have been a study in itself. Hence, when including all functions in one study, some extent superficial- but nevertheless a holistic understanding can be gained. However, this holistic knowledge is valuable in multiple ways. The holistic knowledge achieved in this study, contributes with a broader- and a more systemically comprehension of development and diffusion of charging infrastructure in the area of Oslo and its surroundings. In the light of this, the thesis is providing policy advices, which may be assumed to be of public interest. In addition, the thesis tries to contribute conceptually, in the sense of highlighting the role of infrastructure in innovation studies, as well as being explorative by analysing the dynamic of infrastructure through the framework of technological innovation systems.

The UN recently published a new climate report that ascertains that global warming is in all probability anthropogenic. This indicates the importance of environmentally friendly governance. Furthermore, there has recently been a general election in Norway. During the election campaign, environmental issues have received much attention, which has shown a clear environmental awareness in society. The election resulted in a governmental change, which one can assume will lead to a change of direction in Norwegian environmental politics among others. It will be interesting to see how the shift of government will influence the climate- and innovation policy, and what changes that will be made in relation in future improvement in conditions for development and diffusion of charging infrastructure in the future. This would be interesting to analyse in a future study.

7.0 REFERENCES

Andersen, A. D., (2008, June). *Emergence of the Biofuel Sector in Brazil and in the US: the Role of Innovation Policy with focus on Public Procurement*. Presented at Globelics Academy 2008 on Innovaton and Economic Development, Tampere, Finland. Retrieved July 4th 2013, from *https://smartech.gatech.edu/bitstream/handle/1853/43457/Andersen_GA08.pdf*

Andersen, A. D., & Wicken, O., (2013, June). Low-Carbon Infrastructure and Systems of Innovation. No transitions without trasmission? Presented at *4th International Conference on Sustainability Transitions,* Zurich.

Avere (2012). Norwegian Parliament extends electric car iniatives until 2018. Retrieved 30.09.13, from July 23th 2013, from http://www.avere.org/www/newsMgr.php?action=view&frmNewsId=611&section=&type=&SGLSESSID=tqiice0pmjdclt7l4q0s3s1o27

Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., & Rickne, A. (2008). Analyzing the Functional Dynamics of Technological Innovation Systems: A scheme of analysis. *Research Policy*, *37*(3), 407-429.

Betz, Frederick (2011) *"Managing Technological Innovation: Competetiv Advantage from Change"*. (3rd edition, 221-240). Hoboken, New Jersey: John Wiley & Sons.

Carlsson, B., Jacobsson, S., Holmén, M., & Rickne, A., (2002). Innovation Systems: Analytical and Methodological Issues. *Research Policy 31*(2) 233-245.

Christensen, C. M., (2003). *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail.* Boston: Harvard Business School Press.

Civitas (2012). *Helhetlig utbyggingsplan for infrastruktur til ladebare biler i fylkene Akershus, Hedemark, Oppland og Østfold*. Retrieved 5th August 2013, from http://www.ostfoldfk.no/stream_file.asp?iEntityId=13994

Corvellec, H., Campos, M. J. Z., & Zapata, P., (2012). Infrastructures, Lock-in, and Sustainable Urban Development: The Case of Waste Incineration in the Göteborg Metropolitan Area. *Journal of Cleaner Production 50*, 32-39.

Cowan, R., & Hultén, S., (1996). Escaping Lock-in: The Case of the Electric Vehicle. *Technological Forecasting and Social Change 53*(1) 61-79.

Dunn, K., (2010). Interviewing. In Hay, I., (Eds.) *Qualitative Research Methods in Human Geography.* (3rd ed., pp- 101-137) Don Mills: Oxford University Press.

Edquist, C., (2005). Systems of innovation, perspectives and challenges.In Fagerberg, J., Mowery, D. C., & Nelson, R. R., (Eds.) *The Oxford Handbook of Innovation.* (pp. 181-208) New York: Oxford University Press.

EMN.no. Retrieved from June 15th 2013, from http://www.electricmobility.no/visjon-og-maal/cms/13

Energi i Norge (2009). Energibransjen *leder an i utbygging av ladepunkter*. Retrieved August 28th 2013, from http://www.energinorge.no/nyheter-om-nett-og-system/energibransjen-leder-an-i-utbygging-av-ladepunkter-article7588-239.html

Energi i Norge (2010). En suksessoppskrift for utbygging av ladepunkter. Retrived August 30th 2013, from http://www.energinorge.no/energi-og-klima/en-suksessoppskrift-for-utbygging-av-ladepunkter-article7799-437.html

Fagerberg, J., (2005). Innovation: A Guide to the Literature. Fagerberg, J., Mowery, D. C., & Nelson, R. R. (Eds.) *The Oxford Handbook of Innovation.* (pp. 1-27) New York: Oxford University Press.

Figenbaum, E. & Amundsen, A. (2013). *Ladestasjoner for elbil.* Retrieved August 8th 2013, from http://miljo.toi.no/c-4-6.htm

Freeman, C., (2001). A hard landing for the "New Economy? Information technology and the United States national system of innovation. *Structural Change and Economic Dynamics 12*(2) 115-139.

Frydenlund, S,. (2013) *Nå blir det 400 nye ladepunkter i Oslo.* Retrieved August 11th 2013, from http://www.elbil.no/ladestasjoner/1037-na-blir-det-400-nye-ladepunkter-i-oslo

FuelCellToday (2013). *Fuel Cells and Hydrogen in Norway.* Retrieved May 10th 2013, from http://www.fuelcelltoday.com/analysis/surveys/2013/fuel-cells-and-hydrogen-in-norway

Geels, F. W., (2002). Technological transitions as evolutionary reconfiguration process: a multi-level perspective and a case-study. *Research Policy 31*(8-9), 1257-1274.

Geels, F. W., (2007). Transformations of Large Technical Systems: A multilevel Analysis of the Dutch Highway (1950-2000) *Science, Technology, & Human Values, 2*(2) 123-149.

Grønn bil. Retrieved August September 18th 2013, from http://www.gronnbil.no/elbiluniverset/kart.php#zoom=4&tr=71.23334825491027,56.444476074218755&bl=54.039295359972414,-30.567242675781245&m=1&reg=0

Grønn kontakt (2013) *Sluttrapport for forretningsmodeller, avregnings- og betalingsløsninger: Fase 2.* Retrieved July 22nd 2013, from http://www.transnova.no/wp-content/uploads/2012/07/Sluttrapport-Forretningsmodellprosjekt.pdf

Hafslund.no. *Nett.* Retrieved September 14th 2013, from http://www.hafslund.no/om-hafslund/artikler/les_artikkel.asp?artikkelid=330

Hekkert, M., P. & Negro, S. O., (2008). Functions of innovation systems as a framework to understand sustainable technological change: Empirical evidence for earlier claims. *Technological Forecasting & Social Change 76*(4) 584-594

Hughes, T. P., (1987) The Evolution of Large Technological Systems. Bijker, W. E., Hughes, T. P., & Pinsh. T., (Eds) *The Social Construction of Technological System: New Directions in Sociology and History of Technology.*(pp. 51-82). Cambridge: MIT Press.

Jacobsson, S., (2008). The emergence and troubled growth of "biopower" innovation system in Sweeden. *Energy Policy 36*(4), 1491-1508.

Jacobsson, S., (2011). Systembygging for ny energi. Hanson, J., Kasa, S., & Wicken, O., (Eds.) *Energirikdommens paradokser, Innovasjon som klimapolitikk og næringsutvikling.* Oslo: Universitetsforlaget.

Jacobssen, Steffan and Bergek, Anna (2004). Transforming the engery sector: the evolution of technological systems in renewable energy technology. *Industrial and Corporate Change 13*(5), 815-849.

Kaijser, A., (2004). *The dynamics of infrasystems: Lessons from history.* Retrieved May 29th 2013, from http://www.eawag.ch/forschung/cirus/lehre/fruehere_veranstaltungen/hs08/downloads_ewv/Kaijser_2004.pdf

Kearns, R. A. (2010). Seeing with Clarity: Undertaking Observational Research. In Hay, Iain (Eds.) *Qualitative Research Methods in Human Geography.* (3rd edition, pp. 241- 258). Don Mills: Oxford University Press.

Kvisle[1], H. H.,(2013) *3.746 ladepunkt for elbiler i Norge.* Retrieved September 14th 2013, from http://www.elbil.no/prosjekter/nobil/884-3746-ladepunkt-for-elbiler-i-norge

Kvisle[2], H. K., (2013) *Pangstart på årets elbilsalg!* Retrieved August 9th 2013, from http://www.elbil.no/elbiler/914-pangstart-pa-arets-elbilsalg

Ladestasjoner.no. *Leverandøroversikt.* Retrieved September 17th 2013, from http://www.ladestasjoner.no/ladehjelpen/praktisk/11-leverandoroversikt

Levende historie.no. *Da elbilen var størst.* Retrieved May 29th 2013, 2013. http://www.levendehistorie.no/levende/forsidearkiv/da_elbilen_var_stoerst

Markard, J. (2010, November) *Transformation of Infrastructures: Sector Characteristics and Implications for Fundamental Change.* Presented on third Annual Conference on Competition and Regulation in Network Industries, Brussel. Retrieved August 2nd 2013, from http://crninet.com/2010/2010%20coh%20d.pdf

Markard, J. & Truffer, B. (2006). Innovation processes in large technological systems: Market liberalization as a driver for radical change? *Research Policy 35*(5) 609-625.

Markard, J. & Truffer, B. (2008, November). Technological innovation systems and the multi-level perspective: Towards an integrated framework. *Research Policy 37*(4) 596-615.

Norsk elbilforening (2013). *Årsberetning Norsk Elbilforening 2012 til mars 2013.* Retrieved September 3th 2013, from http://www.elbil.no/om-elbilforeningen/brosjyreroversikt/finish/3-elbilforeningen-dokumenter/104-sakspapirer-til-arsmote-2013

Nørbech, T. E., (2011). *Norge på elbil-toppen.* Retrieved August 18th 2013, from http://www.transnova.no/norge-pa-elbil-toppen/

Ringvold. J., (2013). *El-motorvogn parkering.* Retrieved August, 21st 2013, from https://www.baerum.kommune.no/Organisasjonen/Kommunaltekniske-tjenester/Vei-og-trafikk/Parkering/Elmotorvogn-parkering/

Rip, A., & Kemp, R., (1998). Technological change. In Rayner. S., & Malone, E. L., (eds.) *Human Choice and Climate Change*: *Vol. II: Resources and technology.* (Pp. 327-399). Columbus, Ohio: Batelle Press.

Román, T. G. S., Momber. I., Abbad, M. R., & Miralles, Á. S., (2011). Regulatory Framework and business models for charging plug-in electric vehicles: Infrastructure, agents, and commercial relationship. *Energy Policy 39 (10)* 6360-6375.

Smith, K. (1997). Economic Infrastructures and Innovation Systems. In Edquist, Charles (Eds.) *Systems of Innovation: Technologies, Institutions and Organizations* (pp. 86- 103). London: Pinter.

Smith, K., (2000). Innovation as a Systemic Phenomenon: Rethinking the Role of Policy. *Enterprise & Innovation Management Studies 1*(1), 73-102.

Smith, K., (2002). *What is the "Knowledge Economy"? Knowledge Intensity and Distrubted Knowledge Bases*. In *UNI/INTECH discussion paper series.* Retrieved July 23th 2013, from
http://eprints.utas.edu.au/1235/1/2002-6.pdf

Smith, K., (2009). *Climate change and radical energy innovation: the policy issues*. TIK Working Paper, No. 20090101. Retrieved May 30th 2013, from
http://ideas.repec.org/p/tik/inowpp/20090101.html

Tidd, J. & Bessant, J., (2009). *Managing Innovation: Integrating Technological, Market and Organizational Change.* (4th edition). Chichester: John Wiley & Sons Ltd.

Transnova (2012). *Prosjektrapport etter 3 år.* Retrieved September 13th 2013, from
http://www.transnova.no/wp-content/uploads/2012/06/Transnova-rapport.pdf

Unruh, G, C., (2000). Understanding carbon lock-in. *Energy Policy, 28*(12) 817- 830.

Vethe, K. O., (2011). WWF-sjefen skryter av elbilfrelste Asker-folk. Retrieved September 19th 2013, from http://www.budstikka.no/nyheter/wwf-sjefen-skryter-av-elbilfrelste-asker-folk-1.6512037

Vooren, A. v. d. & Alkemade, F., (2011, April). Infrastructure dependent Technologies: escaping lock-in ant the role of policy. Presented at DIME Final Conference, Maastricht. Retrieved June 9th 2013, from http://final.dime-eu.org/files/vooren_D1.pdf

Vooren, A. v. d. & Alkemade, F., (2012). The diffusion of infrastructure dependent technologies: A simple model. June 9th 2013, from http://www.dime-eu.org/files/active/0/vanderVoorenAlkemade.pdf

Vooren, A. v. d., Alkemade, F. & Hekkert, M, P., (2012). Effective public resource allocation to escape lock-in: The case of infrastructure-dependent vehicle technologies. *Enviromental Innovation and Societal Transitions, 2* 98-117.

Yin, R. K., (2009). *Case Study Research: Design and Methods.* (4th edition), Los Angeles: SAGE Publications.

Appendix:

Interview guide, The Norwegian EV-association

Inform the interviewee about informed consent.

Ask if it is acceptable to use audio recorder.

Background

What role does the Norwegian Electric Vehicle Association play in increasing the use of electric vehicles in Norway?

Challenges

What are the challenges you see with regards to implementing charging infrastructure?

Charging station technology is developing rapidly, do you feel there are any challenges connected to this?

Cooperation
What kind of cooperation do you have with public and private actors?

Would you say there is too little cooperation between entities working with infrastructure?

Have you heard about Electric Mobility Norway?

If yes: How do you think Electric Mobility Norway can contribute to increase electric vehicle mobility in Norway?

Motivation
What is your motivation for working with electric vehicles?

Do you wish for more government involvement/regulation in order to increase EV infrastructure?

Knowledge
In relation to implementing charging stations, do you feel there is enough knowledge in this area?

Are you collecting any data from already established EV infrastructure?

If yes, does this information correspond with you expectations?

Resources

To what extent do you believe funding is an obstacle in order to implementing charging infrastructure?

What do you think is the reason EV charging infrastructure has not reached even further than it does today?